Pine Needle Briquettes: A Renewable Source of Energy

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Abstract

The study was undertaken to investigate the physico-chemical properties of pine needle in the preparation of biomass briquettes. Pine Needle Briquettes (PNB) were prepared using the piston press mold with clay as binder in the ratio of 80:20. Both the physical and combustion properties of the pine needle and pine needle briquettes were carried out in the laboratory. The result shows that pine needle as the good source for briquetting with the moisture content of 9.76%. In addition, the number of hole present help the briquette burn efficiently with the efficiency of 27.01% which is higher than that of fuelwood (15.55%). There was no or little smoke after the initial burning of briquettes which shows comparative advantage of the PNB as a cooking fuel and space heating in the rural population of mountain. Further, particulate matter emitted after burning the briquette (0.570 mg/m^3) was below the guideline set by the Environment Protection Agency (EPA). Thus, we can say that PNB can be used as a renewable fuel, with combustion characteristics (5230kcal/kg) very similar to firewood. The environment will benefit noticeably because the briquettes combustion reduces the amount of burned residues in open space, reduce the forest fire and more importantly the pollution.

Keywords

Pine Needle; Briquette; Fuelwood; Combustion Characteristics

Introduction

Many of the developing countries produce huge quantities of agro residues but they are used inefficiently causing extensive pollution to the environment. The major residues are rice husk, coffee husk, jute sticks, bagasse, mustard stalks, pine needle and cotton stalks. Sawdust, a milling residue is also available in huge quantity. Apart from the problems of transportation, storage, and handling, the direct burning of loose biomass in conventional grates is associated with very low thermal efficiency and widespread air pollution because they are bulky, heterogeneous in size and shape and might differ in density. In addition, the conversion efficiencies are as low as 40% with particulate emissions in the flue gases in excess of 3000 mg/Nm^3 (Grover & Mishra, 1996). There are numerous ways to resolve these problems, of which briquetting and/or pelleting are the most commonly utilized technologies (Kaliyan & Morey, 2009). This entails condensing the previously comminuted biomass into densified particles of uniform size, shape and density. According to Shaw (2008), an advantage of the densification of loose, small and high moisture content biomass is that the compression generally increases the calorific value of the fuel. The bulk density of loose biomass, which is typically about 40 - 200 kg/m^3 can also be increased to densities as high as 600 – 800 kg/m^3. Thus, briquette making has the potential to meet the additional energy demands of urban and industrial sectors, thereby making a significant contribution to the economic advancement of developing countries like Nepal. However, in order to make a significant impact as a fuel source, there is a need to improve and promote its technology of production (Grover & Mishra, 1994). For achieving the desired success, the briquette press should be inexpensive, simple and easy to repair.

The aim of the present study is to determine the physico-chemical properties, combustion characteristics and emission tests of the Pine Needle Briquette (PNB). In addition it justifies PNB as an economical and eco-friendly way for addressing both the issues of waste management and energy shortage.

Materials and Methods

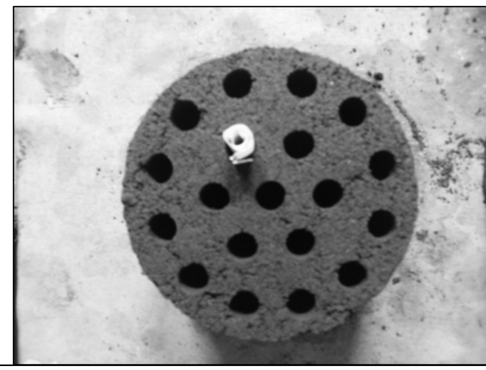
The pine needle sample was collected from the Budole Village Development Committee (VDC) of Kavre during the period of June 9, 2011. The collected sample was dried in the green house to remove its moisture before the charring. After drying for few days the sample was charred as suggested by Karve et al. (2001). The char from the retorts were taken out and was grinded to dust by Grinder Mill. After grinding the char to fine particles it was mixed with clay in the ratio of 80:20 proportion. The mixture of biomass char and additatives with the required amount of water, mixture was formed. This mixture was used to make the briquettes with the help of the piston press mold available at Nepal Academy of Science and Technology (NAST) laboratory. The briquettes produced using this mold are then sun dry for three to five days to remove the moisture from it.

Proximate analysis (moisture content, ash content, volatile matter content, and fixed carbon content) was carried out according to JIS M 8813 and calorific value of the sample was determined with Toshniwal Digital Bomb calorimeter (Model: CC01/M2A). The performance analysis of the produced briquettes was tested using the standard water-boiling test (Water boiling test version 1.5, Shell Foundation) in traditional stoves available at NAST. In the study, combustion tests were conducted to understand the combustion characteristics of the briquette fuels. The smoke from the combustion of the fuel briquettes were evaluated using Bacharach Oil Burner Smoke Scale while the particulate matters, $PM_{2.5}$ was measured during the water boiling test using HaZ Dust EPAM-500. Besides, ignition temperature was determined by igniting briquette sample at the base of the drought free corner. The time required for the flame to ignite the briquette was recorded as the ignition time using stop watch (Wilaipon, 2008).

Results and Discussion

In this study, PNB was prepared and physico chemical parameters were tested. Beehive briquettes provide poor communities with a clean-burning, carbon neutral, low cost cooking source. The charcoal briquette shown in picture below is called a "beehive" briquette. It is cylindrical in shape, weighs about 472 grams, and differs from other charcoal briquettes due to the vertical holes that run through it. The holes enable a flow of oxygen and controlled burning which creates a light blue flame. The large size of the briquette about 13cm in diameter allows it to burn for approximately 1-2 hours. In addition, the briquette is smokeless while burning. The hope is that these attributes will resonate with users and they will consider using this fuel product over other charcoal products, woody biomass, or kerosene.

TABLE 1 PHYSICAL CHARACTERISTICS OF THE BRIQUETTE SAMPLES

Parameters	Pine Briquette
Photographs	
Appearance	Black color, Cylindrical shape with 19 hole
Composition	80% fine pine char and 20% clay
Average Diameter (d)	13cm
Average Height (h)	8.8cm
Diameter of Hole	1.3cm
Weight	472gm
Density	0.055g/cm^3

Proximate analysis of the briquette was done to know the carbon content of the fuel. Further, it also provides information related to moisture content, volatile matter present and ash content in the fuel cell. Thus, studying these characteristics of the fuel is very important to know the characteristics of the fuel (Table 2).

Moisture affects the combustion efficiency negatively and the moisture content should typically be as low as possible (Demirbas, 2004). There are many factors to consider before a biomass qualifies for use as feedstock for briquetting.

TABLE 2 PROXIMATE ANALYSIS OF PINE NEEDLE, PINE NEEDLE CHAR AND PNB

Characteristics	Pine Needle	Pine Needle Char	PNB
Mean Moisture Content (%)	9.76	7.500	6.89
Mean Ash Content (%)	4.37	5.390	11.21
Mean Volatile Matter Content (%)	70.03	17.960	29.04
Fixed Carbon Content (%)	15.83	69.150	52.85
Picture Showing the Proximate Analysis Sampling			

Apart from its availability in large quantities, it should have the following characteristics; it should have low moisture content. In the study, the moisture content of the pine needle was 9.76% dry basis which is within the acceptable operating moisture content of 8-12% for making briquetting (Eriksson & Prior, 1990). However, the moisture limit in most cases can be up to 15% for briquetting of materials, although some materials with up to 20% moisture content can be densified in a piston press. It should be noted that high moisture content above 10% will pose problems in grinding and excessive energy is required for drying. The moisture content obtained in this work is safe for briquette production. According to Bamgboye and Bolufawi (2009), the biomass materials should not also be too dried because for drier material there will be friction which may increase energy demands. Thus, average moisture content of the relaxed briquette should be 7.15% which is okay for this purpose.

Biomass residues normally have much lower ash content (except for rice husk with 20% ash) but their ashes have a higher percentage of alkaline minerals, especially potash. Pine needle charcoal had 5.39% of ash content (Table 2), which lies in the good quality charcoal (1.2% to 8.9%) range set by FAO (1987). During our study we find the mean ash content of PNB is 11.21% which is lower than that of coal with mean ash content 33.47% (Singh et al., 1996). The low values of ash content obtained could be due to the high heating value of the briquettes. Thus, we can say the PNB is better alternative of coal used in brick kiln. According to the research conducted by Agni Group of Companies biomass briquettes have low ash content in comparison to coal (25 to 40%) resulting least boiler ash disposal problems.

According to Grover and Mishra (1996), the ash content of different types of biomass is an indicator of slagging behaviour of the biomass. Generally, the greater the ash content, the greater the slagging behaviour. But this does not mean that biomass with lower ash content will not show any slagging behaviour. The temperature of operation, the mineral compositions of ash and their percentage combined determine the slagging behaviour. If conditions are favorable, then the degree of slagging will be greater. Minerals like SiO_2 Na_2O and K_2O are more troublesome. Many authors have tried to determine the slagging temperature of ash but they have not been successful because of the complexity involved. Thus, slagging of biomass ash during gasification is a major problem (Higman & Burgt, 2003).

The volatile matter of PNB was 29.04% (Table 2) which is lower than that of coal (42.20%). According to the report published by FAO (1985) volatile matter in charcoal can vary from a high value of 40% or more down to 5% or less than 5%. In addition, the volatile matter of pine charcoal was 17.960% (Table 2), which is in range between 20 to 25% purposed by FAO (1987) as good quality charcoal. Charcoal produced at high temperature will have lower value of volatile matter than charcoal produced at low temperature. Moreover, the high value of volatile charcoal tends to be stronger, heavier, harder and easier for the ignition than low volatile charcoal. Therefore, high volatile charcoal is easier to ignite but may burn with smoky flame while low volatile charcoal is difficult to ignite and burns with less smoke. Consequently, high volatile charcoal is preferable for domestic charcoals that can be use in any purposes such

as barbecue, cooking and heating, while other utilizations as metal manufacture and chemical purification prefer low volatile charcoal (Dionco-Adetayo, 2001).

Fixed carbon content is the amount of the carbon present in the sample. Among other tested briquettes, PNB has high carbon content (52.85%) compared to the briquette from coal (18.59%). FORPRIDECOM (1979) recommended the charcoal for domestic use should content 80.5% of fixed carbon, while for the industrial charcoal is recommended to have 86.7% of fixed carbon. On the other hand, the quality smokeless domestic wood charcoal has been specified to consist 75% of fixed carbon or more, while the industrial wood charcoal has been specified to contain not less than 85% of fixed carbon (Sayakoummane & Ussawarujikulchai, 2009). Thus, we can say that pine biomass is good for making the biomass briquette having 69.15% fixed carbon content (Table 2). According to Hindi (1994) the proportion of fixed carbon can be controlled through maximum temperature and its residence time during the carbonization process, which seems true with the research of Dionco-Adetayo (2001). They further added that the charcoal with high volatile matter is lower in fixed carbon and these charcoal briquettes tends to be harder, heavier, stronger and easier to ignite than high fixed carbon charcoal briquette.

Another most important feature of a solid fuel is its calorific value (Tosun, 2007). It determines the commercial value of the fuel. In the present set of experiments, the calorific value of PNB was 5230kcal/kg which is higher than rice rusk, saw dust and Banmara (*Mikania micrantha*) briquettes (Pandey & Dhakal, 2011). This means that with the same amount of fuel, more energy can be generated by using the PNB. There are different factors that affect the calorific value of the briquette i.e. the difference of the environmental conditions as using different temperature in carbonization process, the use of modern machine in the compression process of briquette charcoal. In addition, the amount of inorganic matter in biomass also affects its ultimate calorific value (Strehler, 2000).

Efficiency of the Briquettes

Thermal efficiency is the ratio of thermal power of the product gas produced to the thermal power of the input briquette biomass material supplied. It gives general idea about the how much energy from briquetting biomass material is effectively utilized. Generally thermal efficiency of briquetting biomass depends upon the moisture content of briquettes. Pine needle briquettes were selected for water boiling test for checking their suitability in domestic use as fuel. It was observed that the briquettes were burnt completely in traditional stove and gave uniform flame (Fig 1). Very little ash was left after burning. The preliminary water boiling test showed average thermal efficiency of 27.01%, which is higher than that of fuelwood 15.55% (Singh et al., 2001).

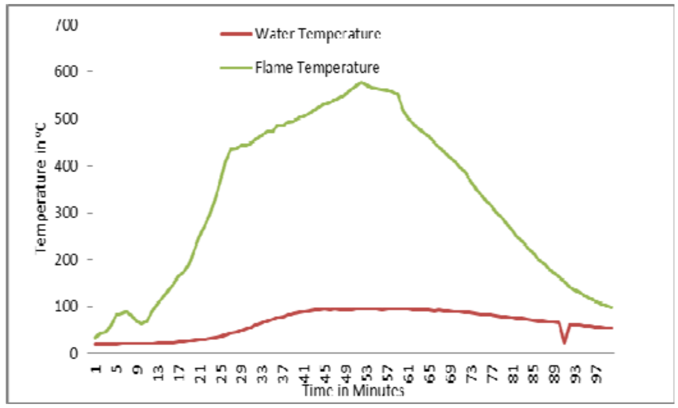


FIG. 1 TIME VS. TEMPERATURE GRAPH

Ignitation Temperature

Ignitation temperature is the lowest temperature at which combustion begins and continues in a substance when it is heated in air. Further, ignition of the briquettes fuel has been explained by the shrinking core model of burning of a briquette ball. The burning takes place at the surface layer of the briquette reducing the size of the burning ball gradually (Kim et al., 2000).

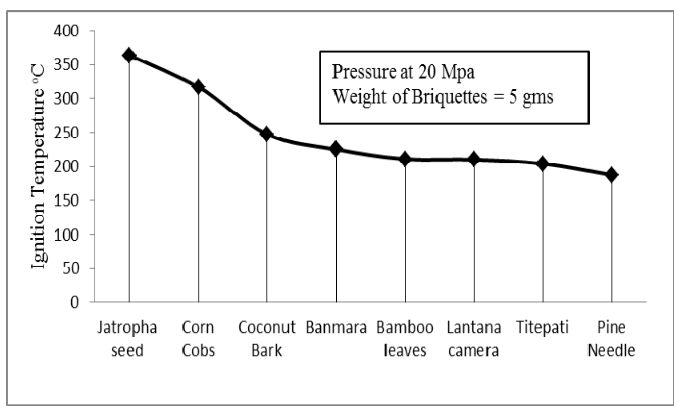


FIG. 2 IGNITION TEMPERATURE VERSES DIFFERENT BIOMASS BRIQUETTES

The results showed the ignition temperature of pine needle was 187.6°C which is lower than other biomass (Fig 2). In addition, pine needle has the lower ignition time compared to other. This shows that the pine needle have the better fuel properties than the other biomass. It has been found that the ignition temperature decreases with increasing amount of volatile matter for different fuels (Zhang et al., 1992). Studies showed that ignitation temperature depends on large number of parameters, including particle size, sample size, bed height, heating rate, oxygen concentration and pressure (Chen et al, 1995; Sun & Zhang 1998)

Smoke Index Test

This test of smoke gives the index of smoke emitted during the combustion or ignition of BHB; however it doesn't give the amount of flue gases present in the smoke emitted from BHB. The smoke index of the PNB is indicated in table 3.

TABLE 3 SMOKE INDEX

S.N	Ignition Condition	Checking Time	Smoke Index	Remarks
1	Initial Burning	1-2 minutes	2-3	The smoke produces during the firing of briquettes
2	Burning of briquettes	After 2 minutes	0-1	There is hardly any smoke

The table 3 shows that there is hardly any smoke after 2 minutes of burning. But in case of traditional fuel such as fuelwood and cow dung, there is highest smoke for the first 20 minutes (Singh et al., 2001). These characteristics clearly indicate the comparative advantage of the PNB as a cooking fuel and space heating in the rural population of mountain.

Particulate Matter Emitted

Particle pollution, called particulate matter or PM, is a combination of tiny specks of soot, dust, and aerosols that are suspended in the air we breathe. $PM_{2.5}$ is particles less than 2.5 micrometers and poses the largest health risks. Because of their small size (less than one-seventh the average width of human hair), fine particles can lodge deeply in lungs and heart causing premature death (www.epa.gov/pmdesignations/faq. htm). In order to minimize the risk, Environmental Protection Agency (EPA) 2006 strengthen the 24-hours $PM_{2.5}$ standard from 65μg/m^3 in 1997 to 35μg/m^3, and retained the current annual $PM_{2.5}$ standard at 15μg/m^3 (www.airquality.utah.gov/publicinterest/about_pollutants/about_pm.htm).

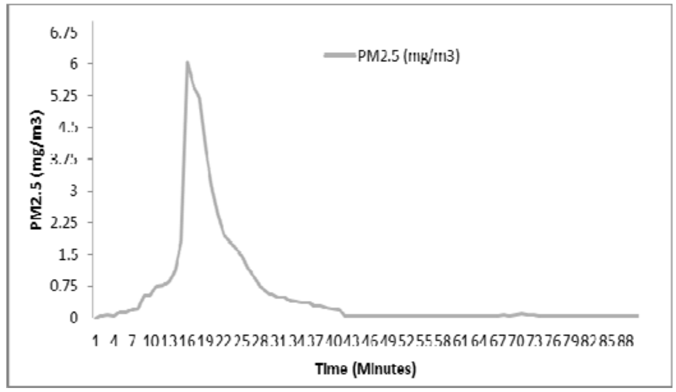


FIG. 3 TIME VS. TEMPERATURE GRAPH

When the PNB was burnt, the particulate matter ($PM_{2.5}$) data were recorded by HAZ dust within an interval of 1 minute. The results show the peak in the curve (Fig. 3) due to the consequence of firing of the briquette from scrap paper which produces excessive smoke. After the briquette started to ignite, the $PM_{2.5}$ concentration sharply decreased and followed a fairly constant value for the rest of the testing period. An average 24 hours mean $PM_{2.5}$ test conducted by ENPHO as a part of research for AEPC/ESAP showed that the average 24 hours mean $PM_{2.5}$ as 2.127 mg/m^3 using the traditional cooking stove. The test of briquettes showed a mean $PM_{2.5}$ as 0.570 mg/m^3. The result shows that the PNB are cleaner fuel than raw biomass resulting in the decrease in $PM_{2.5}$ concentration by nearly 73%.

Conclusions

The physico-chemical characteristics (moisture content, volatile matter content, ash content, calorific value, etc.) of biomass have been studied for the purpose of briquetting. The combustion tests showed that biobriquettes have better combustion and fuel characteristics with higher combustion gas temperature and lower amount of smoke emissions. Proximate analysis showed the pine needle as an excellent raw material for briquetting due to low ash content, low moisture content and relatively high carbon content with the calorific value of 5230kcal/kg. The test of water evaporation undoubtedly suggests its use in the

industrial boilers and kilns for steam generation and heat transfer activities. Finally, the lower amount of smoke emission, higher calorific values, ability to burn longer with stable and uniform temperatures than fuelwood recommends PNB as good briquettes.

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